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Indoor air problems and the perceived social climate in schools: A multilevel structural equation analysis

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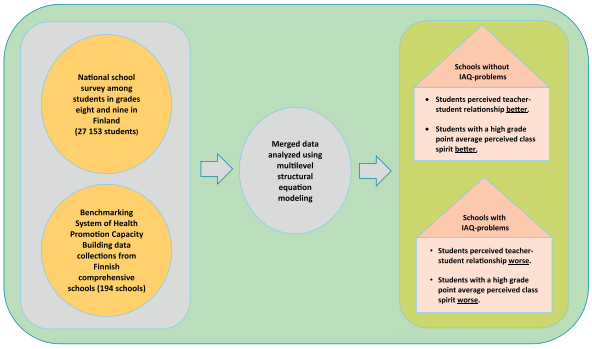
HIGHLIGHTS

- We studied whether schools' IAQ problems associated with their social climate.
- Questionnaire data were analyzed with the multilevel structural equation modeling.
- Focus on two spheres: atmosphere and anthroposphere
- Perceived social climate worse in schools with observed IAQ problems.
- Problems in school's physical environment could undermine school's social climate.

GRAPHICAL ABSTRACT



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ABSTRACT

Indoor air problems in schools appear to influence learning outcomes and absence rates. However, previous research has not investigated whether indoor air problems influence the social climate of schools. Therefore, we studied whether indoor air problems observed in schools associate with students' perceptions of the teacher-student relationship and class spirit. The nationwide sample of Finnish schools (N = 194 schools/27153 students) was analyzed using multilevel structural equation modeling. Data on the schools' social climate collected from students were merged with independently collected data on observed indoor air problems from school principals. We found that the teacher-student relationship was reported to be worse in schools with observed indoor air problems compared to those without observed indoor air problems. Furthermore, the reported class spirit was worse in schools with observed indoor air problems, but

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Psychosocial effect
Lower secondary school
Class spirit

only among students with a high grade point average. Our findings indicate that indoor air problems may affect the student-perceived social climate.

1. Introduction

Problems in schools' indoor air quality (IAQ) are widespread. For example, some 24% of schools in Finland, 20% in the Netherlands, and 40% Spain were estimated to have moisture problems, such as dampness or mold (Haverinen-Shaughnessy et al., 2012). Furthermore, many studies have found that a large proportion of schools are inadequately ventilated (Haverinen-Shaughnessy et al., 2015; Toyinbo et al., 2016; WHO, 2015). Such problems can increase the risk to students' health (Annesi-Maesano et al., 2012; Borràs-Santos et al., 2013), absence rates (Mendell et al., 2013; Simons et al., 2010), and decreased academic performance (e.g., standardized test scores) (Toyinbo et al., 2016; Mendell et al., 2013; Haverinen-Shaughnessy and Shaughnessy, 2015).

Despite these findings, little is known about whether and how poor IAQ associates with the students' perception of *social* climate in schools. The social climate reflects, for instance, the goals, norms, interpersonal relationships and teaching practices, organizational patterns, and school facilities present in a specific school (Cohen et al., 2009; Zullig et al., 2010). Poor student-perceived social climate associates with students' decreased well-being and academic performance (Cohen et al., 2009; Zullig et al., 2010; Anderson, 1982; Thapa et al., 2013), lower self-esteem (Way et al., 2007) and problems in their school adjustment (Kuperminc et al., 1997; Loukas and Murphy, 2007), for example. Given that the perceived social climate plays an important role in students' psychosocial well-being and learning, it is essential to study how schools' IAQ problems relate to it. The need to study the effects of IAQ on the *social* climate in schools is acknowledged in the "indoor air research" literature as well (Magzamen et al., 2015).

1.1. Student-perceived social climate and indoor air problems in schools

Although there is no previous research assessing whether and how schools' IAQ problems relate to the student-perceived social climate, some indirect evidence suggests that there may be an association between them. Previous research has associated schools' IAQ problems with increased rates of teachers' sick leave and decreased well-being (Ervasti et al., 2012; Sahakian et al., 2008), and it may induce interpersonal conflicts as well as anxiety and fear (Lahtinen et al., 2002). Furthermore, it has been shown that teachers, who perceive their school's physical environment unsatisfactory, report more negative attitudes and lower moral toward their work and notice more problems in the school's social climate than teachers who perceive the environment as satisfactory (Earthman and Lemasters, 2009; Uline and Tschannen-Moran, 2008; Uline et al., 2009). Finally, also principals' perceptions of their school's physical environment has been associated with their understanding of the school's ability to deliver instruction (Duyar, 2010).

However, it is unlikely that IAQ problems influence only school personnel. First, given that school's organizational culture and teachers' well-being and attitudes relate to the student-perceived social climate (Cassidy et al., 2016; Elovainio et al., 2011; Hoglund et al., 2015; Virtanen et al., 2009), it is plausible that also students in schools with IAQ problems report lower social climate than students in schools without such problems. Furthermore, previous research indicates that also students' perceptions of their school's physical environment associate with how they perceive the school's social climate (Zullig et al., 2010; Plank et al., 2009). Finally, students' absence rates have been found to be higher in schools with poor IAQ than in schools without such problems (Simons et al., 2010), which may also reflect issues in the social climate, since the social climate associates with school absenteeism (Kearney, 2008). Based on the evidence, it appears that schools' IAQ problems may relate to factors which constitute the student-perceived social climate, such as perceived social support, discipline, and peer relationships, in many ways.

1.2. The present study

In this study, we focus on two highly relevant factors of the student-perceived social climate: perceived quality of teacher-student relationship and perceived class spirit (i.e., the classroom's emotional climate) (Cohen et al., 2009; Schaps, 2005). These factors are very influential for students' academic performance, school engagement, health, and health-related behaviors, for example (Jia et al., 2009; McNeely and Falci, 2004; Wang and Eccles, 2012). Therefore, it is important to know whether and how IAQ problems in schools relate to these factors. Our first research question asks whether the perceived teacher-student relationship and class spirit among lower secondary school students differ between schools with observed IAQ problems and schools without such problems. Based on the literature cited above (Ervasti et al., 2012; Lahtinen et al., 2002; Uline and Tschannen-Moran, 2008; Elovainio et al., 2011), we hypothesize that students in schools with IAQ problems report worse perceived quality of the teacher-student relationship and class spirit than students in schools without such problems (H1).

Our second research question asks whether the associations between *student-level characteristics* (e.g., gender) and the student-perceived social climate are different in schools with and without IAQ problems. The need to study this issue is based on previous research showing that students' perceptions of their school's social climate is associated with many student-level characteristics, such as gender, socioeconomic status, ethnicity, social support, and academic performance (Thapa et al., 2013; McGrath and Van Bergen, 2015; Wyrick and Rudasill, 2009); different students perceive the social climate of their school differently. Given that not only student characteristics but also contextual factors can have effects on the student-perceived social climate (McNeely et al., 2002), we also tested whether the association between *school-level characteristics* (e.g., school size) and the student-perceived social climate are different in these two school contexts. Analyzing these interactions was considered important since is provides information on whether there are certain types of students or schools that are especially susceptible to report poor teacher-student relationship or poor class spirit when facing IAQ problems. Given that there are no previous studies considering this issue, no hypothesis is posed.

2. Material and methods

2.1. Data and participants

The data were obtained from two sources: a) the School Health Promotion Study (SHP) 2013, focusing on comprehensive school students in grades eight and nine (14–16 years old) and b) the Benchmarking System of Health Promotion Capacity Building (BSHPCB) data collections from comprehensive schools in 2013 (for more details, see Finell et al., 2017). The questionnaire of BSHPCB is usually filled in by the school's principals. Two variables from BSHPCB were used in the analysis. The first variable measured if and when the triennial inspection required by Health Care Act 1326/2010 had been carried out in the school. This regulatory inspection is done in co-operation with the

representatives of the school (e.g., a principal), the health authorities, and authorities responsible for construction and maintenance of the school building. It includes a number of factors (not just IAQ related) which can influence the well-being of the school community. The inspection of the indoor environment includes review of existing documents, such as results from possible questionnaires on IAQ and health, IAQ measurements, and other building related reports as well as a building walkthrough focusing on areas where problems have been found or suspected (see Finell et al., 2017; Hietanen-Peltola and Korpilahti, 2015).

The second variable measured whether or not there were biological exposures observed in the school during this regulatory inspection (see Section 2.2.2). BSHPCB questionnaire also asks about physical and chemical exposures. However, we focus only on the item measuring biological exposures here because these issues, especially dampness and mold ("moldy schools") have been under intensive public concern since 1990's in Finland. In the future, it would be interesting to perform comparative analyses on the other two items to test whether the associations with schools' social climate would be different. For the analysis, we included only those schools where a) the inspection was carried out in 2012 or 2013 and b) where 1) biological exposures were identified during the inspection but the problems had not been remediated or 2) no indoor air problems were identified. This means that 73 schools (N = 10,181 students, 27%) were excluded from the group of schools where the regulatory triennial inspection was carried out in 2012 and 2013. In these schools a) the biological exposures were not included in the inspection, b) problems were found and they were already corrected or c) no information were provided (see Measures). Sixteen schools with fewer than 10 students were also excluded from the analysis (total of 66 students, 0.2%). In addition, respondents who reported their age as at least two years younger or three years older than the average age of their classmates were excluded from the analysis (n = 64, 0.2%). Two schools with 16 and 12 students were excluded, because they were considered to be school-level outliers (in the teacher-student relationship). The final data consist of 27,153 students from 194 schools. About 63% of the students were from schools without observed indoor air problems (17,127 students from 127 schools).

2.2. Measures

2.2.1. Outcome variables

The perceived quality of the teacher-student relationship was measured by three items: "Teachers are interested in how I am doing", "Teachers treat us, the students, fairly", and "The opinions of students are taken into consideration in the development of school work". The response scale was 1 = fully agree, 2 = agree, 3 = disagree, and 4 = fully disagree. These items have been used in many previous studies as indicators of the teacher-student relationship (Hoglund et al., 2015; Karvonen et al., 2005; Konu et al., 2002). We modeled teacher-student relationship as a latent factor with these three items. The standardized loadings of the confirmatory factor analysis are presented in Table 2. The fit indicators are reported in Results section (see also Supporting information). The Cronbach alpha was 0.63.

The *class spirit* was measured by three items: "The students in my class get along well", "The classroom discipline in my class is good" and "The mood in our class is such that I dare to express my opinion freely". The response scale was the same as above. These items have been used previously by Karvonen and colleagues (Karvonen et al., 2005) as an indicator of class spirit. As above, we modeled class spirit as a latent factor. The standardized loadings are presented in Table 2. The fit indicators are reported in Results section (see also Supporting information). The Cronbach alpha was 0.67. The data source of the outcome variables was the SHP.

2.2.2. Predictor

The BSHPCB survey item "Were the following issues evaluated in the most recent inspection: Exposure to biological agents (indoor air, mold, etc.)" had the following response options: no data available; not included in the inspection; inspected, no deficiencies detected; inspected, deficiencies detected but not yet corrected; inspected, deficiencies detected and corrected. In this study, we focus only on the following options: 0 = inspected, no deficiencies detected and 1 = inspected, deficiencies detected but not yet corrected. The resulting variable is referred to as "observed IAQ problems".

2.2.3. Background variables

Gender (0 = boy, 1 = girl), *age*, *perceived health*, *parental support*, and *education of the mother* were included only at the student-level (see Statistical analyses and Figs. 1 and 2 below). *Perceived health* was measured by the item: "How is your health in general?" The response scale was 1 = very good, 2 = fairly good, 3 = moderate, and 4 = fairly or very poor. The scale was categorized into two categories (0 = very good, 1 = not very good), because only a small proportion reported moderate or bad health. The similar kind of categorization has been used in other indoor air studies (Turunen et al., 2014; Turunen et al., 2017). *Parental support* was measured by a single item: "Can you talk about things that concern you with your parents?" The response scale was 1 = hardly ever, 2 = every once and a while, 3 = fairly often, and 4 = often. The scale was reversed so that 1 indicated good support and 4 low support. *Education of the mother* was measured based on response options 1 = comprehensive school or primary school, 2 = upper secondary school or vocational education institution, 3 = occupational studies in addition to upper secondary school or vocational education institution, 4 = university, university of applied sciences, or other higher education institution, and 5 = no education. The responses were categorized into two categories: 0 = no university degree education, 1 = university, university of applied sciences, or other higher education institution (i.e., university degree). Parents' higher education has shown to relate strongly to many important factors in Finland such as their children's future participation in higher education (Thomsen et al., 2017) and school choice (Kosunen et al., 2016).

Students' self-reported grade point average (GPA) and *ethnic background* were included both at the student- and the school-levels (see Statistical analyses and Figs. 1 and 2). In Finland, grades range from 4 (low) to 10 (high). In the original data, GPA was categorized into eight categories (1 < 6.5, 2 = 6.5–6.9, 3 = 7.0–7.4, 4 = 7.5–7.9, 5 = 8.0–8.4, 6 = 8.5–8.9, 7 = 9.0–9.4, and 8 = 9.5–10). These categories were recoded into three approximately equally sized categories: 0 corresponding to a GPA <7.5, 1 corresponding to a GPA between 7.5 and 8.4, and 2 corresponding to a GPA >8.4. *Ethnic background* was measured by two items: In which country were your 1) mother and 2) father born? The items were recoded so that the value 0 means that one or both parents were born in Finland, whereas the value 1 means that both parents were born outside Finland. Given that immigration on a larger scale started in Finland as late as in the 1990s (Jaakkola, 2009), it is very unlikely that second generation immigrants would have children of the target age. No missing items were accepted. The data source of all the aforementioned background variables was the SHP.

The *school's size* (i.e., number of students) reported in the BSHPCB was used only as a school-level background variable.

2.3. Statistical analyses

Given that in our data, school children were nested within schools, we built and then analyzed a multilevel structural equation model (MSEM). MSEM makes it possible to decompose both the variance and the measurement error of the outcome variables at the student- and school-levels (Heck and Thomas, 2009; Mehta and Neale, 2005). As previously (Finell et al., 2017), we used full information maximum likelihood estimation (FIML) with robust standard errors as an estimation

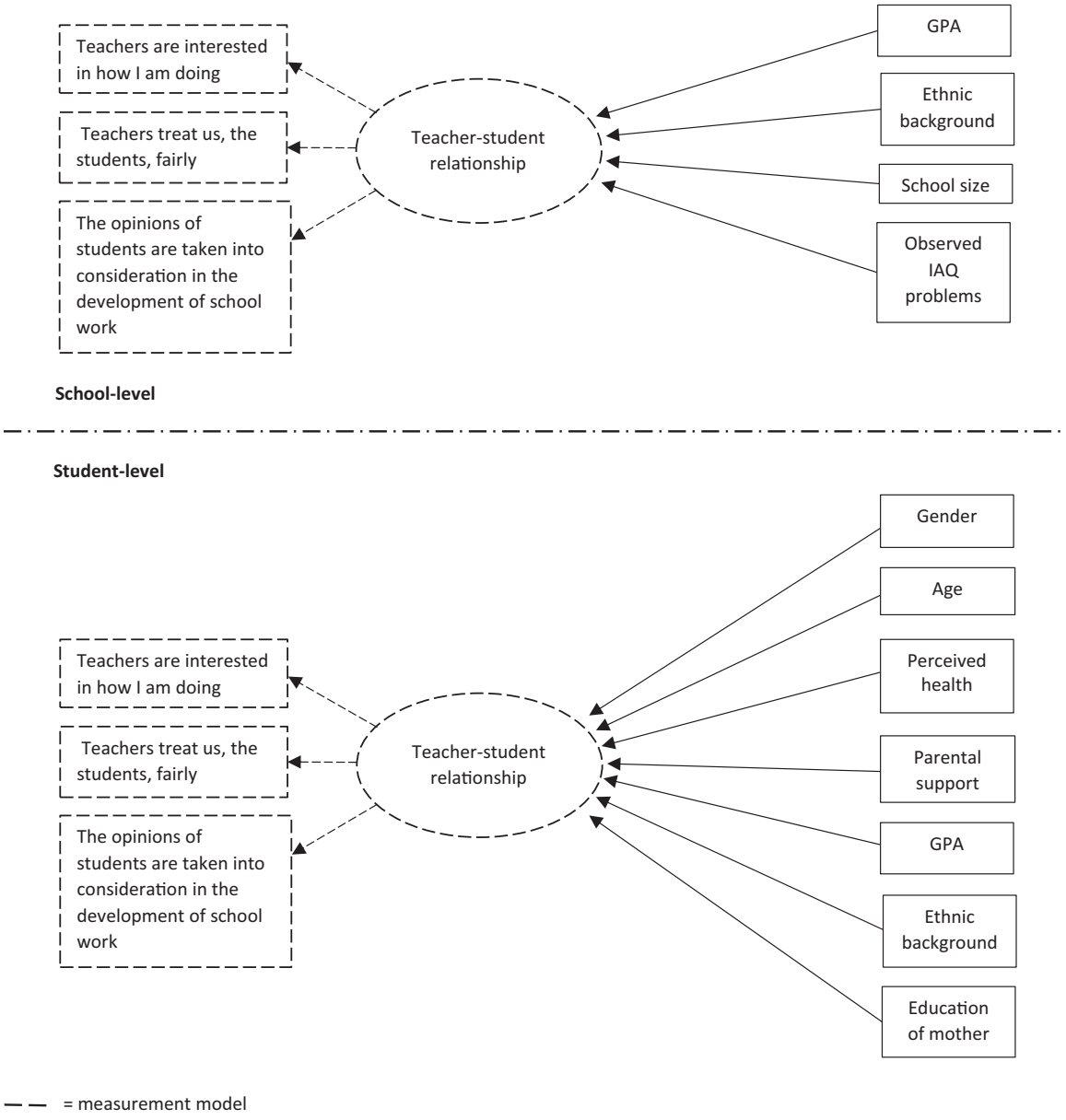

Fig. 1. Hypothesized structural equation model: the teacher-student relationship as a latent outcome variable.

method. Mplus statistical software 7.0 was used in the analysis (Muthén and Muthén, 1998).

First, we tested the model fit of each measurement model (see Figs. 1 and 2). This was done by carrying out a two-level confirmatory factor analysis for both the teacher-student relationship and class spirit variables separately. The loadings were fixed equally at the student and school-levels (Heck and Thomas, 2009) (see Table 2 and further information on measurement models in Supporting information). We used the Standardized Root Mean Square Residual (SRMR), Comparative Fit Index (CFI), and Root Mean Square Error of Approximation (RMSEA) as fit indicators in all the models. SRMR <0.08, CFI > 0.95, and RMSEA <0.06 indicates a good fit between the hypothetical model and the observed data (Hu and Bentler, 1999). Due to the large sample size, the chi-squared test was not used. After the two-level confirmatory factor analyses was carried out, we calculated the intraclass correlations (ICC) of the latent factors (i.e., teacher-student relationship and class spirit) and each predictor (Heck and Thomas, 2009).

In order to test whether observed IAQ problems associated with the teacher-student relationship and class spirit (H1), we estimated two random intercept models (see Figs. 1 and 2). In the random intercept model, the intercept coefficients are allowed to vary across schools. To avoid biased results we used latent factors instead of aggregated variables in both levels as recommended (Lüdtke et al., 2008). This method allowed us to decompose the covariates into two uncorrelated latent factors by Mplus. The first component represents the deviation of students' answers from their school mean (i.e. student level). The second component represents the school mean (e.g. the cluster mean of school-related stress) and it reflects the deviation of each school mean from the grand mean (i.e., school level) (Asparouhov and Muthén, 2006; Muthén and Muthén, 1998-2012). All predictors, except the dichotomous ones, were centered by their grand means.

The hypothesized random intercept models are presented in Figs. 1 and 2. *First*, we used gender, age, perceived health, and parental support only as student-level variables because of their low intraclass correlations (ICC ≤ 0.01) (Heck and Thomas, 2009). We also included the mother's education only at the student-level because it had a high correlation with GPA at the school-level (r = 0.70). Furthermore, the univariate associations between mother's education and outcome

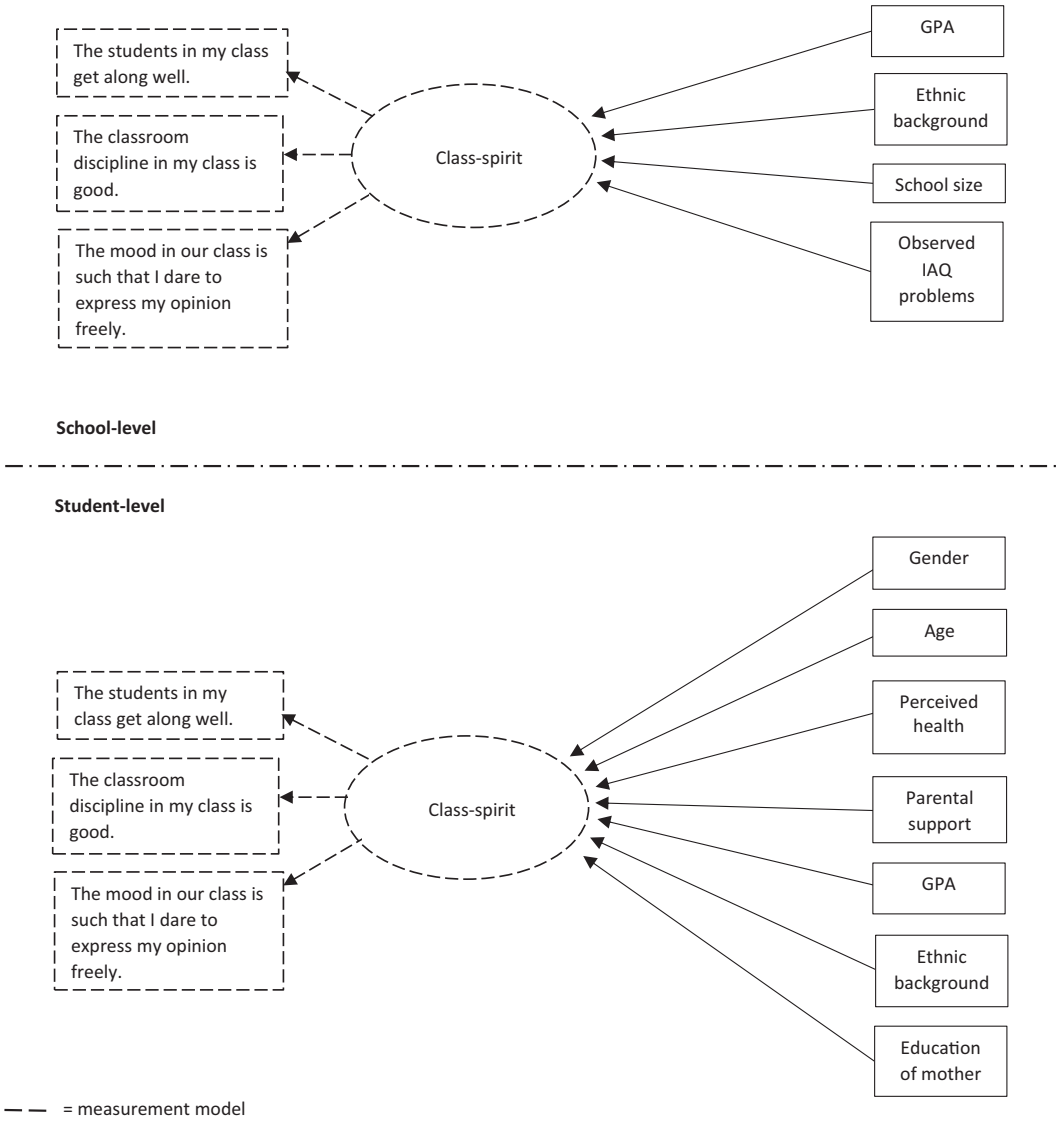

Fig. 2. Hypothesized structural equation model: class spirit as a latent outcome variable.

variables were not significant at the school-level. *Second*, we included school size and observed IAQ problems only at the school-level. *Finally*, we included the ethnic background (ICC = 0.07) and GPA (ICC = 0.04) both at the student and school-levels. This was possible by decomposing each variable into two latent uncorrelated components (one at the student-level and one at the school-level) by Mplus as explained above (Muthén and Muthén, 1998; Asparouhov and Muthén, 2006).

In the text we report the standardized estimates (i.e., when the predictor increases by one standard deviation, the outcome variable increases by the standardized estimate) as well as separate R^2 for both the student- and school-levels provided by Mplus (Muthén, 1998-2004). *In the tables* we also report the unstandardized estimates. When necessary, we report the effect sizes. The effect size was calculated as follows: the unstandardized beta divided by the standard deviation of the factor in the measurement model. This index is equivalent to Cohen's d (Cohen, 1992). Finally, we checked the linearity of the main associations by including the quadratic terms of each variable (except the dichotomous ones) in the models. If the quadratic term was significant ($p < 0.05$), it was included in the final model and reported.

Next, we tested whether observed IAQ problems modified the associations between background variables and outcome variables. Two identical models were built for 1) schools with observed IAQ problems and 2) schools without observed IAQ problems. The models were tested simultaneously (i.e., multigroup two-level structural equation modeling) (Asparouhov and Muthén, 2012). All included background variables were the same as in Models 1a and 1b (see Table 3). The Wald-test was used to determine whether the associations between background variables and outcome variables in the two contexts (i.e., observed IAQ problems vs. no observed IAQ problems) differed significantly from each other ($p < 0.05$).

2.4. Missing values

Gender and observed IAQ problems had the lowest percentages of missing values (0%) and the mother's education had the highest (10%). Values were assumed to be missing at random (MAR) (Rubin, 1976). In order to deal with missing data, we used a full information maximum likelihood (FIML) estimation that produces unbiased values of parameters by determining the value that maximizes the likelihood function based on all available data (Enders and Bandalos, 2001).

3. Results

Descriptive statistics of the observed outcome variables and background variables are presented in Table 1. Only one significant difference in background variables between schools were found: students reported significantly worse perceived health in schools with observed IAQ problems than in schools without such problems (see Table 1).

3.1. The association between observed IAQ problems and the student-perceived schools' social climate

First, we tested the fit of each measurement model (see Figs. 1 and 2) by carrying out a two-level confirmatory factor analysis for each variable separately. In order to do that we fixed the loadings equally at the student and school-levels (Heck and Thomas, 2009). The model fits were good both for the teacher-student relationship (RMSEA = 0.01, CFI = 1.00, SRMR: student-level = 0.00, SRMR: school-level = 0.08) and class spirit (RMSEA = 0.01, CFI = 1.00, SRMR: student-level = 0.00, SRMR: school-level = 0.05). The standardized factor loadings are presented in Table 2 (see further information on measurement models and the fit indicators in Supporting information).

There was a statistically significant variability both in the latent teacher-student relationship - variable within ($\sigma^2_W = 0.204$, $p < 0.001$) and between schools ($\sigma^2_B = 0.010$, $p < 0.001$) and in the latent school spirit - variable within ($\sigma^2_W = 0.276$, $p < 0.001$) and between schools ($\sigma^2_B = 0.012$, $p < 0.001$). The ICC of the both latent variables were 0.05 and 0.04 respectively, meaning that about 4–5% of the variability occurred between schools. Although the ICCs were relatively small, they had strong design effects (DEFF; Ukoumunne et al., 1999; teacher-student relationship: DEFF = 7.46; school spirit: DEFF = 6.76).

Then we estimated two random intercept models (i.e., Model 1a and Model 1b) in order to test whether the perceived teacher-student relationship and class spirit differed between schools with and without observed IAQ problems (see Table 3). The model fits were good both for the teacher-student relationship (Model 1a: RMSEA = 0.02, CFI = 0.97, SRMR: student-level = 0.01, SRMR: school-level = 0.07) and for school spirit (Model 1b: RMSEA = 0.02, CFI = 0.99, SRMR: student-level = 0.01, SRMR: school-level = 0.06). After all background variables were inserted into Model 1a, observed IAQ problems associated significantly with the teacher-student relationship. The effect size was 0.5, indicating a medium-sized effect (Cohen, 1992). However, after all background variables were inserted into Model 1b, observed IAQ problems did not associate significantly with school spirit (see further information on univariate associations in Supporting information).

In Model 1a, the most important student-level background variables were parental support, perceived health, and GPA. The most important school-level background variables were ethnic composition (measured by students' self-reported ethnic background) and the school's average GPA. In Model 1b, the most important student-level background variables were parental support, gender, and perceived health. The most important school-level background variables were school size and the school's average GPA (see Table 3). Model 1a explained 11% of the total variance at the student-level ($R^2 = 0.114$) and 22% at the school-level ($R^2 = 0.222$). Model 1b explained 8% of the total variance at the student-level ($R^2 = 0.077$) and 16% at the school-level ($R^2 = 0.157$), respectively (see Table 3).

3.2. The effect of the school's IAQ problems on the associations between the background and outcome variables

We tested differences on the associations between a) student-level characteristics and the student-perceived social climate and b) school-level characteristics and the student-perceived social climate in schools with and without IAQ problems. In order to test these differences we used multigroup two-level structural equation modeling and Wald-test.

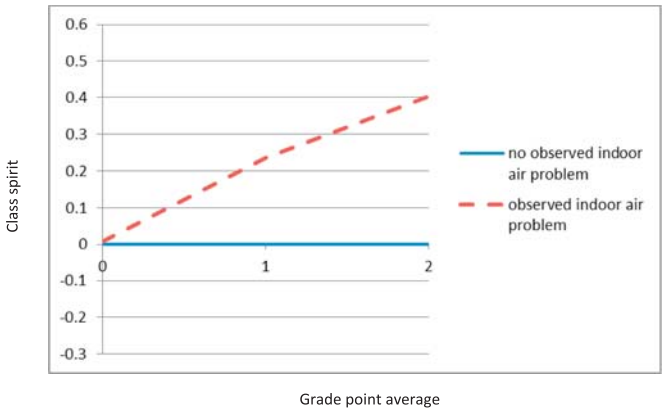

Fig. 3. The mean difference of class spirit between schools with and without observed IAQ problems divided by the standard deviation of class spirit. 0 = GPA < 7.5, $p = 0.948$; 1 = GPA 7.5–8.4, $p = 0.193$; 2 = GPA > 8.4, $p = 0.032$ (N = 193–194 schools).

The association between student-level GPA and class spirit was moderated by observed IAQ problems (Wald-test = 6.04, $p = 0.014$). This association was stronger in schools with IAQ problems (standardized beta = 0.05, $p < 0.001$) than in schools where there were no such problems (standardized beta = 0.00, $p = 0.821$; see further information on univariate associations in Supporting information). In order to better understand this result, we ran three separate analyses. We tested students whose GPA was a) <7.5, b) between 7.5 and 8.4 and c) > 8.4. Except for GPA, the other background variables in these three analyses were the same as in Model 1b (see Table 3). Students with the highest GPA (i.e., > 8.4) perceived more problems in class spirit in schools with observed IAQ problems than in schools without such problems (standardized beta = 0.19, $p = 0.032$). The effect size is 0.4, indicating a small-sized effect (Cohen, 1992). There were no differences between schools among students in the lower GPA clusters (GPA 7.5–8.4: standardized beta = 0.12, $p = 0.193$; GPA < 7.5: standardized beta = 0.01, $p = 0.948$). See Fig. 3.

Furthermore, the linear terms of the parental support and teacher-student associations were significantly different (Wald-test = 4.75, $p = 0.029$) between the two school contexts (no observed IAQ problems: standardized beta = 0.27, $p < 0.001$; observed IAQ problems: standardized beta = 0.23, $p < 0.001$; see further information on univariate associations in Supporting information). The Wald-test between quadratic terms was not significant (Wald-test = 0.50, $p = 0.479$). This small effect indicates that the difference in the perceived quality of the teacher-student relationship between the two school contexts was larger among students with high parental support than students with low parental support. In total, students with low parental support, however, evaluated their teacher-student relationship more negatively than students with high parental support.

4. Discussion

Our main finding was that on average, students in schools with observed IAQ problems reported worse teacher-student relationship than students in schools without such problems. Furthermore, we found that students with a high GPA reported worse class spirit in schools with IAQ problems than in schools without such problems.

Previous research has reported associations between poor IAQ in schools and both health and learning outcomes (e.g., respiratory symptoms, illness absence, and academic performance) (Toyinbo et al., 2016; Mendell et al., 2013; Haverinen-Shaughnessy and Shaughnessy, 2015; Mendell et al., 2016). Our findings contribute to this research by showing that IAQ problems in schools may have an effect on the student-perceived social climate. To our knowledge, this is the first time when

Table 1
Descriptive statistics of the full data by indoor environment context (outcome and background variables N = 24,451–27,153 students/192–194 schools).

	No observed IAQ problems		Observed IAQ problems		p^f
	N	% or Mean (SD)	N	% or Mean (SD)	
Outcome variables					
Teachers are interested in how I am doing (%)					
Fully agree	632	4	337	3	
Agree	6725	40	3746	38	
Disagree	7902	47	4795	48	
Fully disagree	1697	10	1058	11	0.003
Teachers treat us, the students, fairly (%)					
Fully agree	1836	11	899	9	
Agree	10,478	62	6000	61	
Disagree	3713	22	2386	24	
Fully disagree	897	5	629	6	0.000
The opinions of students are taken into consideration in the development of school work (%)					
Fully agree	962	6	426	4	
Agree	8877	53	5050	51	
Disagree	5885	35	3611	37	
Fully disagree	1173	7	786	8	0.000
The students in my class get along well (%)					
Fully agree	3645	22	1993	20	
Agree	9827	58	5684	57	
Disagree	2832	17	1815	18	
Fully disagree	646	4	426	4	0.000
The classroom discipline in my class is good (%)					
Fully agree	1424	8	709	7	
Agree	8464	50	4804	49	
Disagree	5500	32	3428	35	
Fully disagree	1562	9	972	10	0.000
The mood in our class is such that I dare to express my opinion freely (%)					
Fully agree	5046	30	2931	30	
Agree	8332	49	4787	48	
Disagree	2802	17	1705	17	
Fully disagree	785	5	500	5	0.176
Background variables					
Gender (female %)	8430	49	4990	50	0.382
Age (years)	16,635	15.4 (0.6)[a]	9729	15.4 (0.6)[b]	0.639
Perceived health (very good %)	5915	35	3172	32	0.000
Parental support (%)					
Often	4528	27	2574	26	
Fairly often	5424	32	3278	33	
Every once and a while	5534	33	3201	33	
Hardly ever	1325	8	793	8	0.259
Grade point average (%)					
<7.5	5556	33	3320	33	
7.5–8.4	6399	38	3731	38	
>8.4	5054	30	2879	29	0.327
Education of mother (university degree %)	5727	37	3276	37	0.437
Ethnic background (both parents born outside of Finland %)	654	4	346	4	0.125
School size (students per school)	125[e]	332.7[c] (187.5)	67	379.7[d] (187.6)	0.099

[a] Min–max: 13.5–18.2.
[b] Min–max: 13.5–18.1.
[c] Min–max: 67–936.
[d] Min–max: 53–933.
[e] Missing information from two schools.
[f] Age and school size: F-test. All other variables: χ^2 – test.

these effects have been assessed. Given that social climate is shown to influence various factors, such as academic performance, absence rates, and students' psychosocial well-being (Cohen et al., 2009; Kearney, 2008; Schaps, 2005), our findings are important. Furthermore, we found that a school's observed IAQ problems significantly modified the associations between student-level characteristics and the student-perceived social climate. Although these associations were weak, the findings supported the previous research by Finell and colleagues (Finell et al., 2017) by concluding that schools with and without IAQ problems may represent two different social contexts. They also suggest that the social and psychological consequences of IAQ problems in schools result from complex processes where both the students' and school personnel's characteristics play a role.

An important task for future research is to examine why IAQ problems in schools may influence the student-perceived social climate. Our results and the literature provide three potential intertwined paths. The first path relates to the impact of poor IAQ on *school personnel*, for example by decreasing their well-being, increasing sick leave, and causing possible problems in management and decision-making procedures (Sahakian et al., 2008; Lahtinen et al., 2002; Elovainio et al., 2011; Virtanen et al., 2009; Miller et al., 2008). The second path relates to the impact of poor IAQ on *students*. The students' perceived health is associated with the student-perceived social climate (Cohen et al., 2009), as was also found in our study. The third path relates to the poor condition of the school facilities as well as anticipated remediation of the *school building* (Uline and Tschannen-Moran, 2008; Uline et al., 2009). In Finland, school general management and facility management are independent from each other. In other words, school principals and staff do not have a direct role or oversight of the facility management. They can report any issues or concerns but the allocation of funds for school facility management and remediation decisions are made by the municipality technical board. However, remediation processes often result in disturbances (e.g., moving to temporal buildings and/or noise), which can be stressful both to school personnel and students, and may therefore influence the student- perceived social climate.

From a practical point of view, an important question is how it is possible to prevent the potential social consequences caused by IAQ problems in schools. The main task is naturally to investigate and properly remediate indoor air problems in the school building. However, these processes are often slow. In case the remediation is delayed, the prevention of health problems among teachers and students can involve source control (e.g., more frequent cleaning), enhanced ventilation, and exposure prevention (e.g., not using problematic areas). Furthermore, management and decision-making procedures should be developed in order to avoid conflicts inside the school organization and experiences of injustice (Finell and Seppälä, 2017). Open communication and sharing up-to-date (regular, factual) information with school personnel, students, and parents should help to maintain trust between parties.

The strengths of the study include the large and representative sample. The use of multilevel structural equation models has many advantages, including better statistical power compared to models using aggregated school-level data and avoiding spurious findings from using student-level data without taking the hierarchical data structure into account (Mehta and Neale, 2005). The limitations of the study include the cross-sectional design and the use of questionnaire data. Furthermore, we did not have physical measures. This means that we have to rely on principles report on the findings of triennial inspection on biological exposures and that we cannot better distinguish schools based on the factors that have caused their IAQ problems. It is likely that there exists variation in the severity of schools' IAQ problems and their social consequences. We also do not know the degree teachers and students were aware of their school's IAQ problems. In the future, these issues should be further studied using longitudinal data and physical measures. Future research should also detect factors that can mediate the association between school's indoor environment and the perceived social climate. Also possible building-related confounders (e.g., poor

Table 2
Standardized loadings of the teacher-student relationship and class spirit latent variables (student-level: N = 27,018–27,025/School-level: N = 194).

Teacher-student relationship	λ	Class spirit	λ
Student-level		Student-level	
The opinions of students are taken into consideration in the development of school work.	0.65*	The students in my class get along well.	0.73*
Teachers are interested in how I am doing.	0.56*	The classroom discipline in my class is good.	0.54*
Teachers treat us, the students, fairly.	0.60*	The mood in our class is such that I dare to express my opinion freely.	0.63*
School-level		School-level	
The opinions of students are taken into consideration in the development of school work.	0.91*	The students in my class get along well.	0.87*
Teachers are interested in how I am doing.	0.67*	The classroom discipline in my class is good.	0.57*
Teachers treat us, the students, fairly.	0.71*	The mood in our class is such that I dare to express my opinion freely.[a]	1.00*

* $p < 0.001$.
[a] The residual variance is set to zero at the school-level.

sanitary conditions or unpleasant school environment) should be considered.

The present study is part of a larger project aiming to clarify associations between psychosocial factors and IAQ problems among comprehensive school students in Finland. In a previous study, we found associations between both the physical and psychosocial environment and subjective IAQ in schools (Finell et al., 2017). In the present study, psychosocial factors are the outcome variables. Our study underlines the fact that the associations between the perception of IAQ problems and psychosocial factors are highly complex and are likely to influence each other in various ways.

5. Conclusions

Our study found that problems in a school's IAQ associated with the student-perceived social climate. Furthermore, we found that the school's observed IAQ problems significantly modified the associations between student-level characteristics and the student-perceived social climate. Our study points to a need to study schools' IAQ problems from a multidisciplinary perspective in order to better understand how IAQ problems influence students' psychosocial well-being. Furthermore, from practical point of view, when evaluating the urgency of remediation, also IAQ problems' possible social consequences should

Table 3
Parameter estimates for the teacher-student relationship and the classroom's social climate[1] as a function of student- and school-level variables: a random intercept model (N = 27,153 students/194 schools).

	Model 1a Teacher-student relationship		Model 1b Class spirit	
	B (SE)[a]	β (SE)[b]	B (SE)[a]	β (SE)[b]
Student-level				
Gender[c]	−0.06 (0.01)***	−0.07 (0.01)***	0.13 (0.01)***	0.13 (0.01)***
Age[d]	0.01 (0.01)	0.02 (0.01)	−0.02 (0.01)	−0.02 (0.01)
Age squared[e]	−0.06 (0.01)***	−0.06 (0.01)***		
Perceived health[f]	0.08 (0.01)***	0.09 (0.01)***	0.16 (0.01)***	0.15 (0.01)***
Parental support[g]	0.12 (0.00)***	0.26 (0.01)***	0.07 (0.01)***	0.13 (0.01)***
Parental support squared[e]	0.03 (0.00)***	0.06 (0.01)***	0.02 (0.01)***	0.03 (0.01)***
Education of mother[h]	0.05 (0.01)***	0.06 (0.01)***	−0.02 (0.01)	−0.01 (0.01)
Grade point average[i]	−0.06 (0.01)***	−0.11 (0.01)***	0.01 (0.01)*	0.02 (0.01)*
Grade point average squared[e]	−0.02 (0.01)*	−0.02 (0.01)*		
Ethnic background[j]	−0.02 (0.03)	−0.01 (0.01)	0.08 (0.03)**	0.03 (0.01)**
School-level				
Observed IAQ problems[k]	0.05 (0.02)**	0.25 (0.08)**	0.02 (0.02)	0.08 (0.08)
Grade point average[d]	−0.22 (0.09)*[l]	−0.28 (0.10)**	−0.24 (0.09)**	−0.27 (0.10)**
Ethnic background	−0.36 (0.12)**	−0.19 (0.09)*[n]	0.03 (0.19)	0.02 (0.09)
School size[o]	0.01 (0.00)[m]	0.16 (0.08)*	0.01 (0.01)*	0.24 (0.09)*
σ^2_W	0.17 (0.01)	0.89 (0.01)	0.24 (0.01)	0.92 (0.01)
σ^2_B	0.01 (0.00)	0.78 (0.07)	0.01 (0.00)	0.84 (0.08)

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.
[1] A higher value in the teacher-student relationship and the classroom's social climate means more problems.
[a] Unstandardized beta.
[b] Standardized beta.
[c] Scale 0–1 (0 = boy).
[d] Grand mean centered.
[e] Quadratic term. Only if the quadratic term was significant ($p < 0.05$), it was included in the final model and reported. There were no significant quadratic terms at the school-level.
[f] Scale 0–1 (0 = very good health).
[g] Scale 1–4 (1 = good support, grand mean centered).
[h] Scale 0–1 (1 = university education).
[i] Scale 0–2 (0 = GPA <7.5, grand mean centered).
[j] Scale 0–1 (0 = one or both parents are born in Finland).
[k] Scale 0–1 (0 = no observed IAQ problems in the school).
[l] $p = 0.012$.
[m] $p = 0.064$.
[n] $p = 0.027$.
[o] In these models the scale was changed as follows: school size/100.

be taken into account. Timely and effective remediation process not only prevent adverse health effects but can also prevent problems in school's social climate.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2017.12.126.

References

Anderson, C.S., 1982. The search for school climate: a review of the research. Rev. Educ. Res. 52, 368–420.

Annesi-Maesano, I., Hulin, M., Lavaud, F., et al., 2012. Poor air quality in classrooms related to asthma and rhinitis in primary schoolchildren of the French 6 Cities Study. Thorax 67, 682–688.

Asparouhov, T., Muthén, B.O., 2006. Constructing Covariates in Multilevel Regression. Mplus. Web Notes, 11. www.statmodel.com.

Asparouhov, T., Muthén, B.O., 2012. Multiple Group Multilevel Analysis. Mplus. Web Notes, 16. www.statmodel.com.

Borràs-Santos, A., Jacobs, J.H., Täubel, M., et al., 2013. Dampness and mould in schools and respiratory symptoms in children: the HITEA study. Occup. Environ. Med. 70, 681–687.

Cassidy, D.J., King, E.K., Wang, Y.C., et al., 2016. Teacher work environments are toddler learning environments: teacher professional well-being, classroom emotional support, and toddlers' emotional expressions and behaviours. Early Child Dev. Care https://doi.org/10.1080/03004430.2016.1180516.

Cohen, J., 1992. Statistical power analysis. Curr. Dir. Psychol. Sci. 1, 98–101.

Cohen, J., McCabe, E.M., Michelli, N.M., Pickeral, T., 2009. School climate: research, policy, practice, and teacher education. Teach. Coll. Rec. 111, 180–213.

Duyar, I., 2010. Relationship between school facility conditions and the delivery of instruction. Evidence from a national survey of school principals. J. Facil. Manag. 8, 8–25.

Earthman, G.I., Lemasters, L.K., 2009. Teacher attitudes about classroom conditions. J. Educ. Adm. 47, 323–335.

Elovainio, M., Pietikäinen, M., Luopa, P., et al., 2011. Organizational justice at school and its associations with pupils' psychosocial school environment, health, and wellbeing. Soc. Sci. Med. 73, 1675–1682.

Enders, C.K., Bandalos, D.L., 2001. The relative performance of full information maximum likelihood estimation for missing data in structural equation models. Struct. Equ. Model. Multidiscip. J. 8, 430–457.

Ervasti, J., Kivimäki, M., Kawachi, I., et al., 2012. School environment as predictor of teacher sick leave: data-linked prospective cohort study. BMC Public Health 12, 770.

Finell, E., Seppälä, T., 2017. Indoor air problems and experiences of injustice in the workplace: a quantitative and a qualitative study. Indoor Air https://doi.org/10.1111/ina.12409.

Finell, E., Haverinen-Shaughnessy, U., Tolvanen, A., et al., 2017. The associations of indoor environment and psychosocial factors on subjective evaluation of indoor air quality among lower secondary school students - a multilevel analysis. Indoor Air 27, 329–337.

Haverinen-Shaughnessy, U., Shaughnessy, R.J., 2015. Effects of classroom ventilation rate and temperature on students' test scores. PLoS ONE 10, e0136165. https://doi.org/10.1371/journal.pone.0136165.

Haverinen-Shaughnessy, U., Borras-Santos, A., Turunen, M., et al., 2012. Occurrence of moisture problems in schools in three countries from different climatic regions of Europe based on questionnaires and building inspections – the HITEA studyo. Indoor Air 22, 457–466.

Haverinen-Shaughnessy, U., Shaughnessy, R.J., Cole, E.C., et al., 2015. An assessment of indoor environmental quality in schools and its association with health and performance. Build. Environ. 93, 35–40.

Heck, R.H., Thomas, S.L., 2009. An Introduction to Multilevel Modeling Techniques. Routledge, New York, NY.

Hietanen-Peltola, M., Korpilahti, U., 2015. Terveellinen, turvallinen ja hyvinvoiva oppilaitos. Opas ympäristön ja yhteisön monialaiseen tarkastamiseen [A healthy, safe and well-being school. A guide to the multidisciplinary inspection of the environment and the community]. THL, Helsinki.

Hoglund, W.L.G., Klingle, K.E., Hosan, N.E., 2015. Classroom risks and resources: teacher burnout, classroom quality and children's adjustment in high needs elementary schools. J. Sch. Psychol. 53, 337–357.

Hu, L., Bentler, P.M., 1999. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. Struct. Equ. Model. Multidiscip. J. 6, 1–55.

Jaakkola, M., 2009. Maahanmuuttajat suomalaisten näkökulmasta. Asennemuutokset 1987–2007 [Immigrants seen by Finns. Changes in attitude 1987–2007]. An introduction to Multilevel Modeling Techniques. Helsingin kaupungin tietokeskus, Helsinki.

Jia, Y., Way, N., Ling, G., et al., 2009. The influence of student perceptions of school climate on socioemotional and academic adjustment: a comparison of Chinese and American adolescents. Child Dev. 80, 1514–1530.

Karvonen, S., Vikat, A., Rimpelä, M., 2005. The role of school context in the increase in young people's health complaints in Finland. J. Adolesc. 28, 1–16.

Kearney, C.A., 2008. School absenteeism and school refusal behavior in youth: a contemporary review. Clin. Psychol. Rev. 28, 451–471.

Konu, A.I., Lintonen, T.P., Rimpelä, M., 2002. Factors associated with schoolchildren's general subjective well-being. Health Educ. Res. 17, 155–165.

Kosunen, S., Bernelius, V., Seppänen, P., Porkka, M., 2016. School choice to lower secondary schools and mechanisms of segregation in urban Finland. Urban Educ. https://doi.org/10.1177/0042085916666933.

Kuperminc, G.P., Leadbeater, B.J., Emmons, C., Blatt, S.J., 1997. Perceived school climate and difficulties in the social adjustment of middle school students. Appl. Dev. Sci. 1, 76–88.

Lahtinen, M., Huuhtanen, P., Kähkönen, E., Reijula, K., 2002. Psychosocial dimensions of solving an indoor air problem. Indoor Air 12, 33–46.

Loukas, A., Murphy, J.L., 2007. Middle school student perceptions of school climate: examining protective functions on subsequent adjustment problems. J. Sch. Psychol. 45, 293–309.

Lüdtke, O., Marsh, H.W., Robitzsch, A., Trautwein, U., Asparouhov, T., Munthén, B., 2008. The multilevel latent covariate model: a new, more reliable approach to group-level effects in contextual studies. Psychol. Methods 13, 203–229.

Magzamen, S., Mayer, A.P., Schaeffer, J.W., Reynolds, S.J., 2015. Advancing a multidisciplinary research framework on school environment, occupant health, and performance. Indoor Air 25, 457–461.

McGrath, K.F., Van Bergen, P., 2015. Who, when, why and to what end? Students at risk of negative student–teacher relationships and their outcomes. Educ. Res. Rev. 14, 1–17.

McNeely, C., Falci, C., 2004. School connectedness and the transition into and out of health-risk behavior among adolescents: a comparison of social belonging and teacher support. J. Sch. Health 74, 284–292.

McNeely, C.A., Nonnemaker, J.M., Blum, R.W., 2002. Promoting school connectedness: evidence from the national longitudinal study of adolescent health. J. Sch. Health 72, 138–146.

Mehta, P.D., Neale, M.C., 2005. People are variables too: multilevel structural equations modeling. Psychol. Methods 10, 259–284.

Mendell, M.J., Eliseeva, E.A., Davies, M.M., et al., 2013. Association of classroom ventilation with reduced illness absence: a prospective study in California elementary schools. Indoor Air 23, 515–528.

Mendell, M.J., Eliseeva, E.A., Davies, M.M., Lobscheid, A., 2016. Do classroom ventilation rates in California elementary schools influence standardized test scores? Results from a prospective study. Indoor Air 26, 546–557.

Miller, R.T., Murnane, R.J., Willett, J.B., 2008. Do teacher absences impact student achievement? Longitudinal evidence from one urban school district. Educ. Eval. Policy Anal. 30, 181–200.

Muthén, B.O., 1998-2004. Mplus Technical Appendices. Muthén & Muthén.

Muthén, L.K., Muthén, B.O., 1998-2012. Mplus User's Guide. seventh edition. Muthén & Muthén, Los Angeles, CA.

Plank, S.B., Bradshaw, C.P., Young, H., 2009. An application of 'broken-windows' and related theories to the study of disorder, fear, and collective efficacy in schools. Am. J. Educ. 115, 227–247.

Rubin, D.B., 1976. Inference and missing data. Biometrika 63, 581–592.

Sahakian, N.M., White, S.K., Park, J.H., et al., 2008. Identification of mold and dampness-associated respiratory morbidity in 2 schools: comparison of questionnaire survey responses to national data. J. Sch. Health 78, 32–37.

Schaps, E., 2005. The role of supportive school environments in promoting academic success. Getting Results, Developing Safe and Healthy Kids Update 5: Student Health, Supportive Schools, and Academic Success. California Department of Education, Sacramento, CA, pp. 37–56.

Simons, E., Hwang, S.-A., Fitzgerald, E.F., et al., 2010. The impact of school building conditions on student absenteeism in upstate New York. Am. J. Public Health 100, 1679–1686.

Thapa, A., Cohen, J., Guffey, S., Higgins-D'Alessandro, A., 2013. A review of school climate research. Rev. Educ. Res. 83, 357–385.

Thomsen, J.-P., Bertilsson, E., Dalberg, T., Hedman, J., Helland, H., 2017. Higher education participation in the Nordic countries 1985–2010—a comparative perspective. Eur. Sociol. Rev. 33, 98–111.

Toyinbo, O., Shaughnessy, R., Turunen, M., et al., 2016. Building characteristics, indoor environmental quality, and mathematics achievement in Finnish elementary schools. Build. Environ. 104, 114–121.

Turunen, M., Toyinboa, O., Putus, T., et al., 2014. Indoor environmental quality in school buildings, and the health and wellbeing of students. Int. J. Hyg. Environ. Health 217, 733–739.

Turunen, M., Iso-Markku, K., Pekkonen, M., Haverinen-Shaughnessy, U., 2017. Statistical associations between housing quality and health among Finnish households with children - results from two (repeated) national surveys. Sci. Total Environ. 574, 1580–1587.

Ukoumunne, O.C., Gulliford, M.C., Chinn, S., et al., 1999. Methods for evaluating area-wide and organisation-based interventions in health and health care: a systematic review. Health Technol. Assess. 3.

Uline, C., Tschannen-Moran, M., 2008. The walls speak: the interplay of quality facilities, school climate, and student achievement. J. Educ. Adm. 46, 55–73.

Uline, C.L., Tschannen-Moran, M., DeVere Wolsey, T., 2009. The walls still speak: the stories occupants tell. J. Educ. Adm. 47, 400–426.

Virtanen, M., Kivimäki, M., Luopa, P., et al., 2009. Staff reports of psychosocial climate at school and adolescents' health, truancy and health education in Finland. Eur. J. Pub. Health 19, 554–560.

Wang, M.-T., Eccles, J.S., 2012. Social support matters: longitudinal effects of social support on three dimensions of school engagement from middle to high school. Child Dev. 83, 877–895.

Way, N., Reddy, R., Rhodes, J., 2007. Students' perceptions of school climate during the middle school years: associations with trajectories of psychological and behavioral adjustment. Am. J. Community Psychol. 40, 194–213.

WHO, 2015. School Environment: Policies and Current Status. WHO Regional Office for Europe, Copenhagen.

Wyrick, A.J., Rudasill, K.M., 2009. Parent involvement as a predictor of teacher–child relationship quality in third grade. Early Educ. Dev. 20, 845–864.

Zullig, K.J., Koopman, T.M., Patton, J.M., Ubbes, V.A., 2010. School climate: historical review, instrument development, and school assessment. J. Psychoeduc. Assess. 28, 139–152.